

Helios Mission Support

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Project Helios, named after the ancient Greek Goddess of the Sun, is a joint undertaking by the Federal Republic of West Germany and the United States of America, who divide the project responsibilities. Each country has a Project Manager who is responsible for his own country's contribution as determined by the International Agreement. In addition, the two Project Managers act as co-Chairmen of the internationally structured Helios Joint Working Group Meetings which are held semi-annually and alternate between the two countries. The project objective is to launch two unmanned scientific satellites into heliocentric orbits that will come closer to the Sun than any known or planned spacecraft to date for the purpose of obtaining further knowledge about the Sun and its influence upon life on Earth. The plan is to launch the first spacecraft in mid-1974 and the second in late 1975.

Prior volumes of this series described the history and organization of this program, the spacecraft configuration and trajectory, its telecommunications system, and the results of prior Joint Working Group Meetings. This article deals with the activities and highlights of the Sixth Helios Joint Working Group Meeting which was held at JPL in April-May 1972.

I. Introduction

Volume II (Ref. 1, p. 19) of this report series described the *Helios* Project Management organization. It was noted that in addition to the line management organization within the United States and the Federal Republic of West Germany, the International Agreement established a Working Group structure wherein the U.S. and German Project Managers would act as co-Chairmen of semi-annual technical coordination meetings to be held alternately between the United States and West Germany. Initially, these meetings were held at the respective Project Headquarters at Goddard Space Flight Center, Greenbelt, Maryland, and at the Gesellschaft fuer Wel-

traumforschung (GfW) facility in Bonn-Bad Godesberg, West Germany. However, in recognition of the importance of the *Helios* Ground Data System, the co-Chairmen scheduled the Fifth *Helios* Joint Working Group (HJWG) Meeting (October 1971) to be held at Deutsche Forschungs und Versuchsanstalt fuer Luft-Und Raumfahrt (DFVLR), Oberpfaffenhofen, West Germany, which houses the German Space and Operations Center (GSOC). Likewise, the co-Chairmen scheduled the Sixth *Helios* Joint Working Group Meeting at the Jet Propulsion Laboratory, April 26 through May 3, 1972, in recognition of the Tracking and Data System (TDS) support being provided by JPL along with consultation in selected fields of spacecraft technology. The Laboratory appreciated this oppor-

tunity to host this international conference which was attended by 158 official representatives—including some 89 West Germans. In addition, the Sixth HJWG Meeting was supported by a large number of JPL attendees who actively participated in the proceedings. This article will, therefore, be devoted to the highlights of that meeting.

II. Technical Highlights of the Sixth *Helios* Joint Working Group Meeting

A. TDS Subgroup Meetings

1. *General.* Due to the scope of the agenda, the TDS Subgroup met independently on four different occasions during the course of the Sixth *Helios* Joint Working Group Meeting. In addition, individual TDS Subgroup members participated in a number of special splinter group sessions devoted to specific technical topics. The number and scope of these meetings is in itself evidence that *Helios* has progressed past the conceptual design phase and is now deeply engrossed in the detail design phase. Since the latter also involves the detail design of all interfacing elements, such as the DSN, it was fortunate from the TDS viewpoint that the Sixth HJWG Meeting was conducted at JPL. This permitted rapid access to DSN technical resources as the need arose during the conduct of the Working Group meeting. This need did arise on many occasions and the results are documented both in the official minutes (Ref. 2) and in the formal interface agreements documents. Because of this, the following paragraphs will only attempt to highlight the most significant TDS developments that occurred during the Sixth HJWG Meeting.

2. *Near-Earth trajectory.* During the Fifth HJWG Meeting, which was held in October 1971 at Oberpfaffenhofen, West Germany, it was officially announced that *Helios* would employ a *Titan/Centaur*/TE364-4 launch vehicle using a direct-ascent launch trajectory. At that meeting, the Performance, Trajectory and Guidance (PT&G) Working Group recommended that the launch phase perigee altitude be raised from 185 to 926 km (100 to 500 nmi) to avoid the possibility of the *Titan*'s second stage impacting land masses in either Europe or Africa (see Ref. 3, p. 22). As a result of this recommendation, action items were assigned to develop a new set of powered-flight launch trajectories using the 926-km (500-nmi) perigee altitude. This work was accomplished during the period between the Fifth and Sixth Joint Meetings. Analysis of the new trajectories disclosed several interesting phenomena: First, while the angular tracking and doppler rates were higher during the near-vertical ascent phase, these rates dropped very rapidly and came well within DSN tracking capabilities by the time the spacecraft be-

came visible to either the Madrid or Johannesburg, South Africa, DSSs. Second, the higher perigee altitude permits practically continuous spacecraft visibility from land-based stations, thereby eliminating the need for ships and aircraft. Third, starting in mid-July 1974, the daily launch windows experienced in the southern launch corridor (Fig. 1 of Ref. 4, p. 26) have a longer time duration than the corresponding daily launch window in the northern corridor. Partially offsetting these advantages is a fourth factor which is a degradation due to an increase in the space loss (signal strength attenuation) because of the higher perigee altitude. However, the full impact of the latter is not known at this time. Data were presented at the Sixth HJWG Meeting which state the Near-Earth Phase station capabilities. These data must now be processed by the *Helios* Project Office to determine the telecommunications link performance at the higher perigee altitude. However, preliminary calculations indicate that this penalty may not be too severe. Therefore, after reviewing all of the results of the Sixth HJWG Meeting, the U.S. and German co-Chairmen (Project Managers) accepted the PT&G recommendation to use the southern launch corridor for future studies and analyses—but with the provision that all spacecraft, experiment, and ground operational efforts/schedules should remain consistent with a July 1, 1974 launch readiness date (Page 4 of Ref. 2).

3. *Compatibility tests schedule.* As mentioned in the previous issue (Ref. 5), initial *Helios*/DSN compatibility tests were conducted at DSS 71, Cape Kennedy, during April 1972. For these tests, the project employed an Engineering Model (EM) spacecraft transponder, which, due to schedule conflicts, did not contain the (telemetry and command) Data Handling Unit. As a result, the telemetry and command modulation had to be simulated, using specially generated digital waveforms in order to measure the various transponder performance parameters. While these tests were meaningful in themselves, they did not establish true end-to-end telecommunications compatibility; therefore, it was suggested that additional compatibility tests be conducted prior to the availability of the Prototype Model (PM) spacecraft in the fall of 1973 (see Fig. 3 of Ref. 6, p. 31). However, in his opening remarks to the general session of the Sixth HJWG Meeting, the German co-Chairman specifically requested that the individual subgroups study the implications and ramifications of delaying the PM compatibility tests with the DSN until after similar tests have been conducted between the Prototype Model and the German network stations (Ref. 4, p. 23; Ref. 3, p. 18) in order to avoid the expense and schedule delay associated with bringing the Prototype Model to the U.S. for compatibility and environmental tests, returning it to Germany for German network com-

patibility tests, and then returning it to Cape Kennedy to serve as a backup for the Flight Spacecraft. Scheduling all German tests prior to the U.S. tests would eliminate one round trip across the Atlantic. Along with the other subgroups, the TDS Subgroup pondered this question in considerable detail. The TDS Subgroup concluded that a delay in the U.S. compatibility test program would result in no time being available for any fixes necessary between the Prototype and Flight Model Spacecraft—based on the assumption that the German network will not be able to support compatibility tests prior to December 1, 1973 and the Flight Spacecraft is to be launched on schedule in July 1974. The co-Chairmen (Project Managers) weighed this consideration against the fact that the Prototype availability schedule had been delayed to December 1, 1973, which means it cannot meet the October 1973 schedule for compatibility tests in either event. However, the co-Chairmen stated that consideration will be given to the feasibility of utilizing the Engineering Model Spacecraft for the October 1973 DSN tests and the November 1973 launch vehicle mating tests. If this proves to be infeasible, the next compatibility testing opportunity would be with the Prototype at Cape Kennedy in April 1974. The outcome of this feasibility study is not predictable at the present time.

4. Ground Data System. A considerable number of the detailed technical discussions conducted within the TDS Subgroup concerned the characteristics, interfaces and performance of the Ground Data System (GDS). For *Helios*, the Ground Data System comprises all Earth-based elements from the receipt of the spacecraft signal at the stations to the final delivery of the Experiment Data Records (EDRs) to the individual experimenters. It encompasses both the U.S. and German support effort. While the external TDS interfaces with the spacecraft and the experiments were discussed in the respective joint sessions, there were numerous internal interfaces to be discussed within the TDS Subgroup during the Sixth HJWG Meeting. Among these was the definition of the data flow (routing) between the stations and the Project for both the realtime (mission operations) and non-realtime (EDR) modes of operation. An important decision was reached that all data received by the DSSs, whether intended for realtime or non-realtime use, would be routed via the Mission Control and Computing Center (MCCC)¹ for the generation of Master Data Records (MDRs) prior to reformatting and routing the data to the *Helios* Mission Support Area—whether the latter be located at JPL or in Germany. This is particularly important with respect to

the interface between the MCCC and the German Space Operations Center (GSOC) located at Oberpfaffenhofen, West Germany. This routing permits a consistent interface for both Mission Operations data and coordination activities between the U.S. and German supporting networks.

The establishment of a consistent interface has obvious advantages for the realtime conduct of the mission. The non-realtime advantages may not be quite so obvious. For one thing, a consistent interface permits the Ground Data System to allocate within itself the permissible error level that can be tolerated for each element of the system and still meet the experimenters' requirements regarding their data records. For another thing, it permits the Ground Data System to re-examine the classical definition of the division of content between the MDR and the EDR to ensure maximum effectiveness of available resources. Another advantage, though seemingly mundane, is that a consistent interface permits a bit-by-bit specification of the data in each high-speed data block sent over the Ground Communication System between the various elements of the GDS. Such specifications are necessary because these data blocks are processed by computers and a change in data block format necessitates a change in computer software programs and/or subroutines. Since GSOC plans to obtain its computer software via procurement contracts, it is necessary to have these specifications defined at an early date and for the specifications to come under change control to avoid unnecessary contract modification expenses. Toward this end, the telemetry data block format for the MCCC/GSOC interface was established during the Sixth HJWG Meeting, and, in addition, an action item was generated to similarly define the command data block format prior to the next Working Group Meeting. These are examples of the level of detailed technical discussion mentioned in *Section II-A-1*, above.

B. TDS/Spacecraft Telecommunications Joint Meeting

In addition to discussions on the results of the Engineering Model Compatibility Tests and the impact of the new *Helios* trajectory upon Near-Earth Phase coverage, the following topics were discussed in the joint TDS/Spacecraft Telecommunications Meeting:

1. Status of DSS Ground Data System to handle *Helios* telemetry. The DSN experience to date in processing *Pioneer 10* telemetry was of interest to *Helios* since the latter also uses convolutionally encoded telemetry. Unfortunately, only a limited amount of *Pioneer 10* data had been accumulated and analyzed with respect to DSN performance by the time of the Sixth *Helios* Joint Working Group Meeting. In addition, it is difficult to extrapolate

¹The Space Flight Operations Facility (SFOF) at JPL has been renamed the Mission Control and Computing Center (MCCC).

DSN performance regarding the *Pioneer 10* frame length of 384 bits (maximum) to the anticipated performance with the 1152-bit *Helios* frame length. Some 192-bit frame length *Pioneer 10* data had been analyzed which showed a decoding deficiency of between 0.3 and 1.2 dB over preflight predictions. A portion of this deficiency may be attributable to certain preflight calculations which did not consider all of the error sources that exist in an actual receiving station. To reduce this discrepancy, the DSN presented an improved analytical model of DSS telemetry performance for project use in their telecommunications link analyses. In addition, the DSN agreed to provide *Helios* with a complete set of computer simulations, which are presently being run, regarding DSN performance with respect to *Pioneer 10* telemetry, and also to provide the *Helios* Project selected computer simulations based on the *Helios* telemetry frame length, etc. Dissemination of this information is anticipated prior to the Seventh *Helios* Joint Working Group Meeting.

2. *Helios* link design calculations. The project reported that calculations performed since the Fifth HJWG Meeting indicated that a significant reduction in anticipated telemetry performance will be reflected in the next issue of the *Helios* Link Design Control Tables. This reduction, which can total 1.5 dB for the nominal case and as much as 5 dB for the adverse tolerance case, is attributable to both spacecraft and ground station factors. The spacecraft factors include a forced reduction in dc power available to the radio subsystem, plus a better understanding of the actual performance (measured values) of the various elements within the radio subsystem. The ground station factors include adjustments to the analytical model and the incorporation of actual measurement data as mentioned in Section II-B-1, above. In addition, it is anticipated that the next issue of the *Helios* Link Design Control Tables will incorporate the effects of the new 926-km (500-nmi)-perigee powered-flight trajectory mentioned in Section II-A, above. Because this new issuance of the Link Design Control Tables will be used to develop the standard sequence of *Helios* mission events, the DSN agreed to give the document an immediate but thorough review upon its issuance.

C. TDS/Mission Analysis and Operations Joint Meeting

In addition to the foregoing topics, which were also discussed during the joint TDS/Mission Analysis and Operations (MA&O) meeting, the following subjects were also discussed:

1. *Blind acquisition procedures.* The present spacecraft design incorporates a safety feature which shuts off the

spacecraft transmitter in the event of an overload to the spacecraft dc power supply. To re-establish the downlink, it is necessary to send a command to reactivate the transmitter. This may create operational problems, especially in the very early phases of the mission. This factor, plus the complex nature of the associated analyses, led to the establishment during the Sixth HJWG Meeting of a special task team to study the matter in detail. The task team is to be composed of representatives from the TDS and Spacecraft Subgroups, and will be chaired by an MA&O representative.

2. *Data flow.* A detailed discussion was held on the data flow from the DSS through the MCCC to GSOC for telemetry, and from GSOC via the MCCC to the DSS for command data. This discussion reaffirmed the TDS Subgroup's conclusion that the routing should not bypass the MCCC. During the Working Group sessions, splinter groups were able to establish the high-speed data line block format for telemetry flow from the MCCC to GSOC, and an action item was assigned to similarly develop the high-speed data line block formats for command data. In addition, the DSN provided a status report on the operation to date of the *Pioneer 10* Remote Information Center (Ames Research Center) interface with the MCCC. It was duly noted that due to software development delays, *Pioneer* operates in a combination mode: telemetry data bypassing the MCCC, while command data are routed via the MCCC.

3. *Early orbit determination.* Since *Helios* requires an early (10 hours after launch) orbit determination in order to properly structure the Step II maneuver, the DSN presented its recent experience in performing an early orbit determination for *Pioneer 10*. Since the *Pioneer 10* actual launch trajectory followed very close to preflight nominals, its orbit was determined to sufficient accuracy well within the time constraint required by *Helios*. However, it was pointed out that this rapid orbit determination was aided by the existence of the two-way coherent doppler data as opposed to the *Helios* case where the doppler would be non-coherent. Because of the inaccuracies associated with non-coherent doppler, it was recommended that MA&O attempt, during the design of the mission sequence, to obtain as much two-way coherent doppler data as possible during the early mission phases. It was pointed out that the lack of coherent two-way doppler can only be partially offset by data from the Near-Earth Phase Network.

4. *Documentation.* The interface between the Ground Data System and Mission Operations is heavily dependent upon documentation. This is due not only to the fact

that it is necessary to reduce these interfaces to specification form, but also because it is necessary to develop procedures whereby personnel conducting the mission can react quickly and in a predictable manner to both standard and non-standard events experienced during the course of the mission. Further, if one considers computer software programs to fall into the general category of documentation, then one might state that the Mission Analysis and Operations function is more heavily dependent upon documentation than are the other elements of the project. It is, therefore, not surprising that the *Helios* Ground and Operations System (HGOS) (see Ref. 1, p. 20) has been actively developing a Management Plan which is expected to be published in July 1972. This plan not only establishes what documents are to be produced but also establishes a schedule for their publication. The Management Plan not only encompasses such standard documents as the Support Instrumentation Requirements Document (SIRD), but also includes specialized documents required to meet *Helios* program objectives. The status of a few of the key documents was provided during the Working Group Meeting: The SIRD was issued in preliminary form in September 1971. This document is presently being updated to incorporate the launch vehicle requirements; Experiments 11, 12 and 13 requirements; and numerous other changes. It is anticipated that the final version of the SIRD will be published during the summer of 1972.

The *Helios* Software Requirements Documents for telemetry and command data processing received an extensive review at JPL during the week prior to the Sixth HJWG Meeting. These requirements were found to be technically feasible; therefore, once the review comments are incorporated, the document will be officially published.

Documents will also be generated covering the Mission Design, Mission Operations, and the interfaces between MA&O and the other elements of the project—particularly those interfaces between the U.S. and German efforts.

D. TDS/Experiment Joint Meeting

The *Helios* Ground Data System has two major interfaces with the experiments: A realtime interface, and a non-realtime interface. In practice, the realtime interface for the display of science data is considered part of the total Mission Operations display requirements upon the Ground Data System. The non-realtime interface is via the Experiment Data Record (EDR). With respect to the latter, the following important factors were discussed during the joint sessions.

The experimenters defined their telemetry accuracy requirements as follows:

Undetected bit error rate	1×10^{-5}
Frame deletion rate ^a	1×10^{-3}
Dropout rate ^a (after establishment of link between spacecraft and station)	4%

^aFrame deletion rate (1×10^{-3}) is based on data after dropout rate (4%).

After reviewing these requirements, the TDS Subgroup concluded that on a selective basis it appeared that the Ground Data System can perform to these specifications provided there is sufficient signal strength in the spacecraft-to-ground link. As noted above, the latter needs further investigation.

The proposed science data processing plans of both the U.S. and German data centers were presented to the experimenters for their review. The plans satisfied the experimenters' requirements and were accepted.

For further details on this or any of the above-mentioned meetings, the reader is referred to the minutes of the Sixth *Helios* Joint Working Group Meeting (Ref. 2).

III. Conclusions

In the opinion of both the TDS Subgroup and Project Management, the Sixth *Helios* Joint Working Group Meeting was highly productive. Marked progress was made in defining many of the important interfaces. Some of these were resolved to the point where formal specifications can now be generated, while others require further study. In the latter instance, specific actions were assigned participants in order that schedule objectives can be met. In addition, the exchange of technical information during the Sixth HJWG Meeting provided an important base upon which to structure each country's future activities in support of *Helios*. While the actual accomplishment of project activities is achieved within the line management organization of the respective countries, such efforts would be hardly compatible if it were not for the coordination achieved through the mutual understanding derived from the semi-annual Joint Working Group Meetings. The Jet Propulsion Laboratory is, therefore, pleased to have been selected host for the Sixth HJWG Meeting and is looking forward to its participation during the Seventh HJWG Meeting, which is to be held October 25–31, 1972 at Porz-Wahn, West Germany.

References

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